Model-Based Organizational Analysis of an Expeditionary Strike Group (ESG) C^2 Structure

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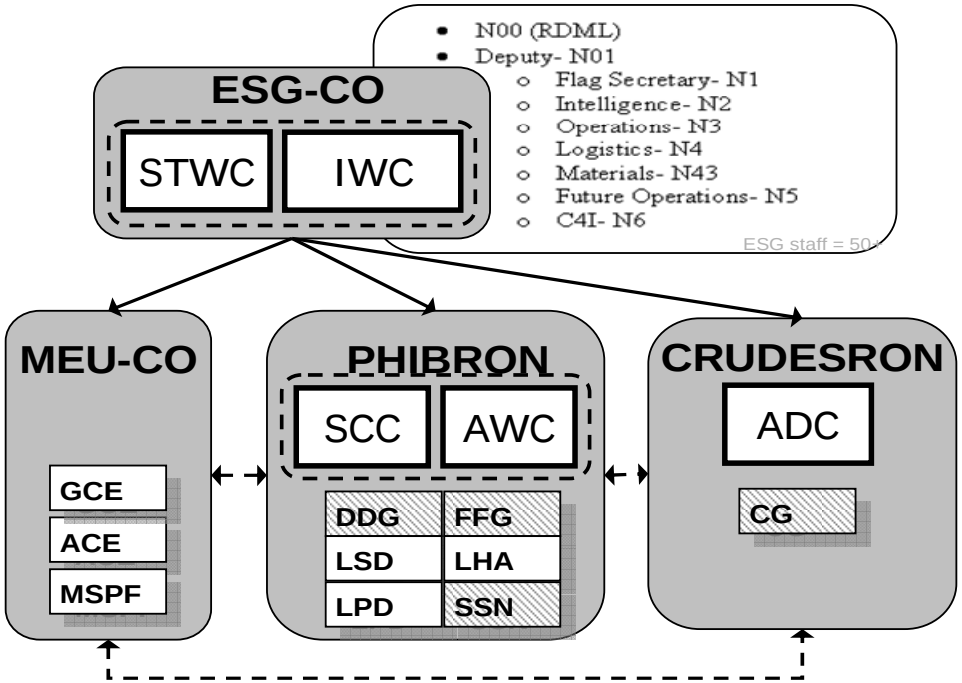
ESG Structure and Analysis Issues



- ESG-CO:
  Expeditionary Strike Group Commander
- MEU-CO:
  Marine Expeditionary Unit Commander
- PHIBRON:
  Amphibious Squadron Commander
- CRUDESRON: AGEGIS Cruiser Commander

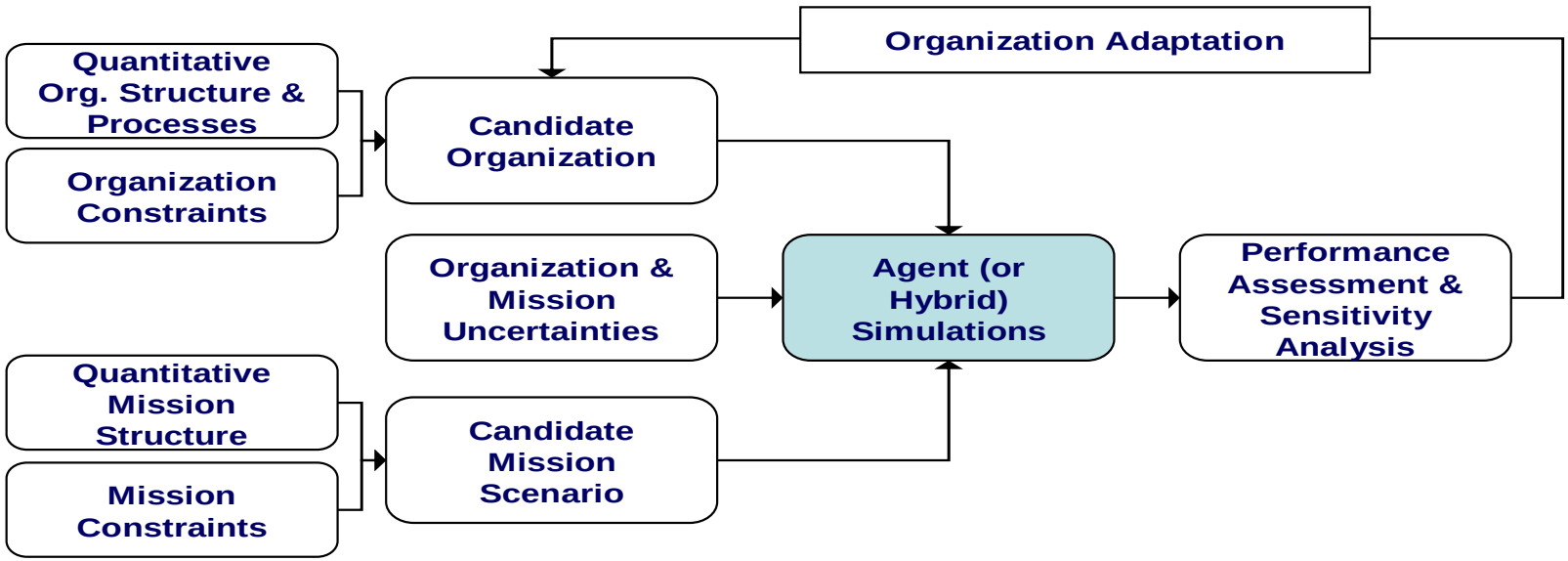
- ADC: Air Defense Commander
- AWC: Amphibious Warfare Commander
- IWC: Information Warfare Commander
- SCC: Sea Combat Commander
- STWC: Strike Warfare Commander

- ACE: Air Combatl Element
- GCE: Ground Combatl Element
- MSPF: Maritime Special Purpose Force
- DDG: Destroyer Ship
- FFG: Frigate Ship
- LSD: Dock Landing Ship
- LHA: Amphibious Assault Ship
- LPD: Amphibious Transport Dock Ship
- SSN: Submarine
- CG: Cruiser Ship

- **Hypothesis**: The presence of dual doctrines (Amphibious and CWC) will introduce high workload on the PHIBRON C^2 node and high external coordination with other C^2 nodes
- **Key Organizational Issue**: hybrid supporting-supported (S-S) relationships
  - How to adopt S-S relationships?
  - how to determine these relationships (static or dynamic)?
  - how to handle conflicts (e.g., supporting multiple concurrent missions), and determining when such relationships break down (e.g., under high workload and dispersed forces)?

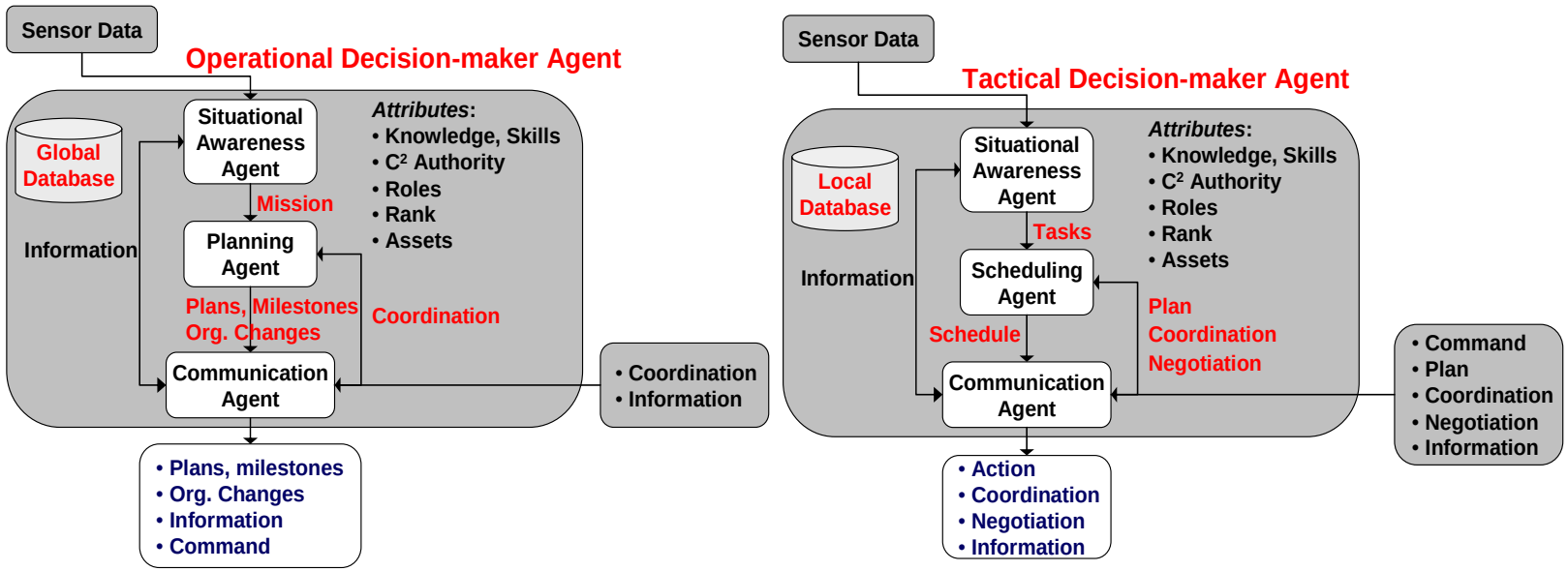
Model-Based Organization Analysis

- Stimulus-Hypothesis-Option-Response (SHOR)-paradigm based Distributed Dynamic Agent/Human-in-the-Loop simulations
- Provides a realistic framework to discern the strong functional dependencies between the mission environment and the organization
- Facilitates the representation of various organizational structures from full hierarchies to networks (heterarchies)
- Allows for a variety of interaction patterns among the decision-makers from a completely centralized to a fully distributed control



SHOR model-based Agent Architecture

The ESG C^2 organization is modeled as a collection of C^2 nodes and assets connected via command, control, communication, and task-asset-DM structure

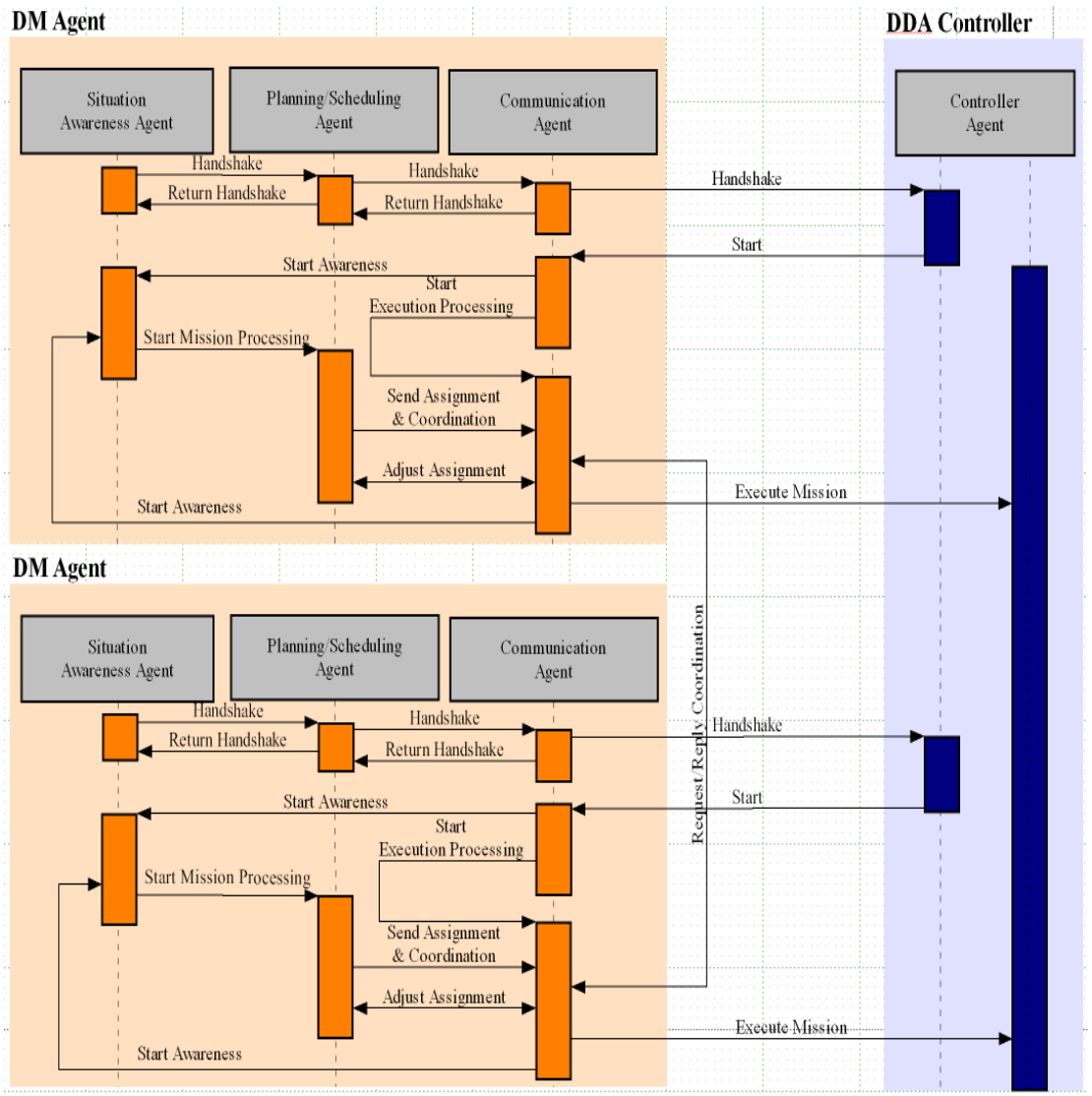


Subagents of Distributed Dynamic Agent (DDA)

- The **SA agent** is responsible for managing the stimulus-hypothesis elements – the identification phase of task processing;
- The **planning/scheduling agent** handles the option element – the allocation phase;
- The **communication agent** manages the response – the prosecution and execution phases of task processing

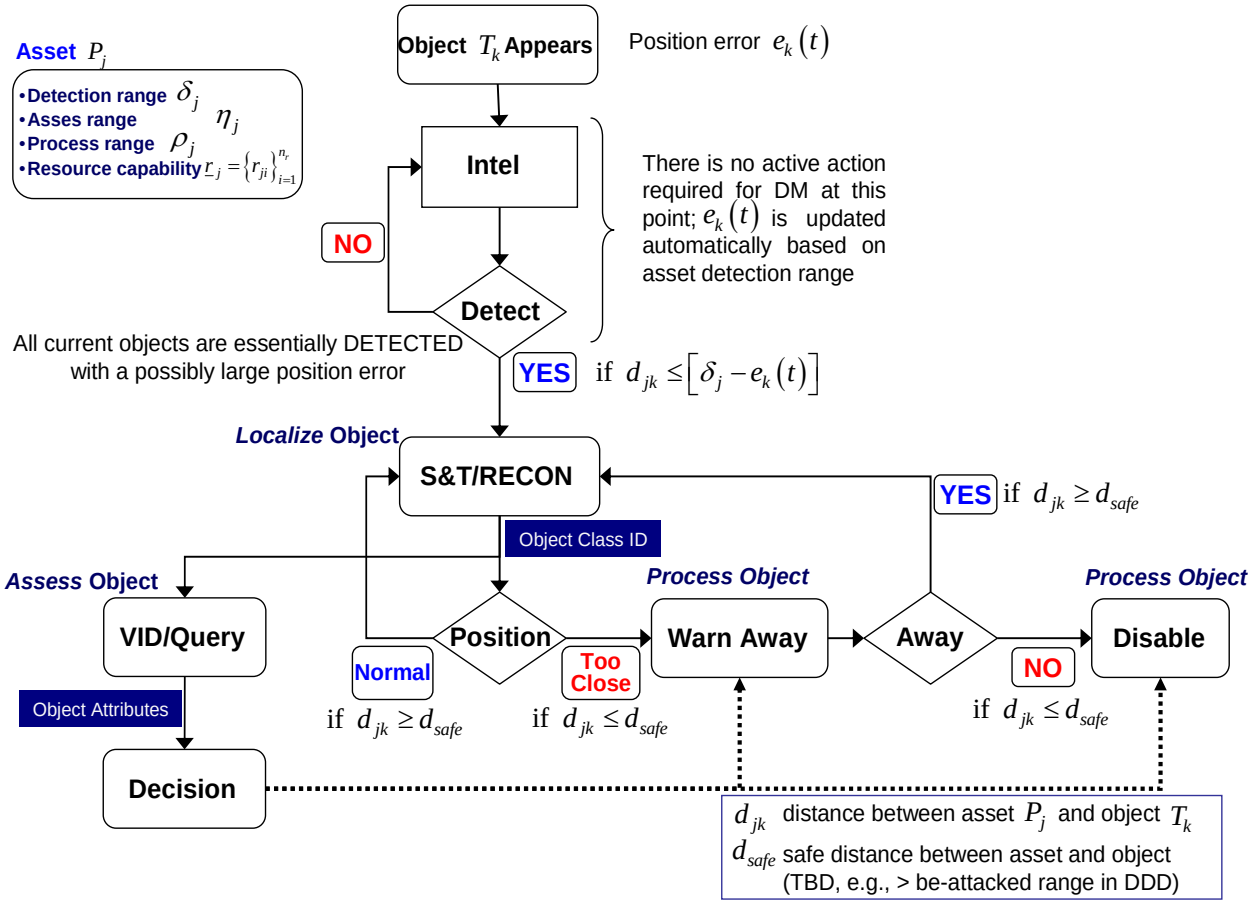
"SHOR" model

Agent – Scenario Interaction



- DDA implementation utilizes the Java Agent Development Environment (JADE)
- DDA Controller initiates the scenario and continuously updates the states of assets and tasks based on resource utilization and task execution status information provided by DDA-based Decision-making (DM) agents
- Data are stored in both local and central databases

MSO-MIO Mission Scenario and Rule of Engagement



The rules of engagement for MIO-MSO related tasks are the following:

- Objects' types, locations, and attributes are initially UNKNOWN to the ESG
- ISR&T determines whether an unknown object is an object of interest, i.e., SHIP
- VID identifies the attributes of the ship, whether small/large, compliant/non-compliant, carrying contraband/not
- It is within the ROE that any ship regardless of attributes should be WARNED-away from ever approaching the ESG assets
- Further actions, such as DISARMING, will be taken if the ship is not backing-off after the warning or if its attributes prove risky

Mission Scenario Design

Maritime Security Operations and Maritime Interdiction Operations: Objects inside a region of containment must be tracked, checked (S&T, Visually Identified, or queried), and properly handled (warned away, boarded, or disabled)

Mission Scenario Design (3x3x3 Factorial Design)

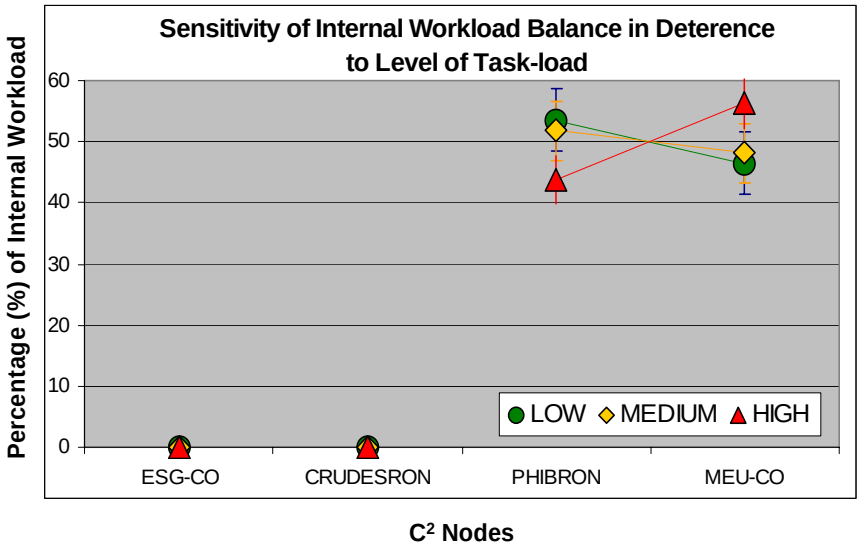
Task-load	Mission Difficulty	Supporting-Supported Relationship
Low: 20 uniformly distributed un-identified objects	Mixed object types: '**Low**' mission difficulty ⇒ all assets can participate in the disabling process	Dynamic assignment (action leader: largest contributor to each action)
Medium: 40 uniformly distributed un-identified objects	S-111: '**Medium**' mission difficulty ⇒ most assets can participate in the disabling process	Navy in supported role
High: 60 uniformly distributed un-identified objects	S-110: '**High**' mission difficulty ⇒ only MSO-DETER assets can participate in the disabling process	Marine in supported role

Object Type	Description	Resource Requirements for Deterrence	Resource Requirements for Disarming
S-000	Ship: small, compliant, no-contraband	MSO-DETER (h)	VBSS-H (o), VBSS-L (o)
S-001	Ship: small, compliant, contraband	MSO-DETER (h)	VBSS-L (h), GUARD (l)
S-010	Ship: small, noncompliant, no-contraband	MSO-DETER (h)	MSO-DETER (l)
S-011	Ship: small, noncompliant, contraband	MSO-DETER (h)	SUW (l), VBSS-L (h), GUARD (h)
S-100	Ship: large, compliant, no-contraband	MSO-DETER (h)	VBSS-H (o), VBSS-L (o)
S-101	Ship: large, compliant, contraband	MSO-DETER (h)	VBSS-H (h), GUARD (m)
S-110	Ship: large, noncompliant, no-contraband	MSO-DETER (h)	MSO-DETER (h)
S-111	Ship: large, noncompliant, contraband	MSO-DETER (h)	SUW (l), VBSS-H (h), GUARD (h)

ID	Resources
1	AW
2	USW
3	SUW
4	ASHORE
5	VID
6	MINE-EOD
7	MIO-INSPT
8	VBSS-HIGH
9	VBSS-LOW
10	ISR-G
11	ISR&T
12	CSAR
13	XPORT
14	MSO-DETER
15	GUARD
16	AMP-GSALT
17	FIRES
18	CAS
19	AARM
20	STRK
21	HADR

Workload Imbalance due to Task Load

Mission Difficulty: Medium; Dynamic S-S Relationships



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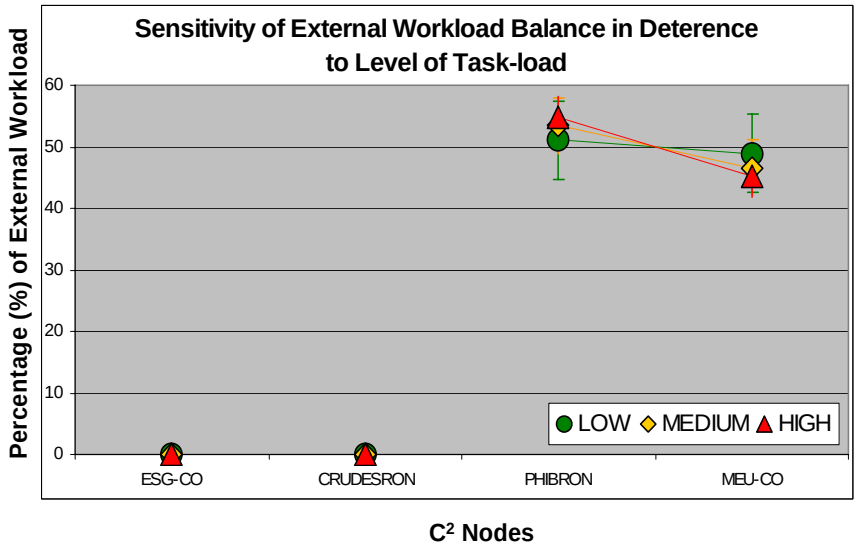
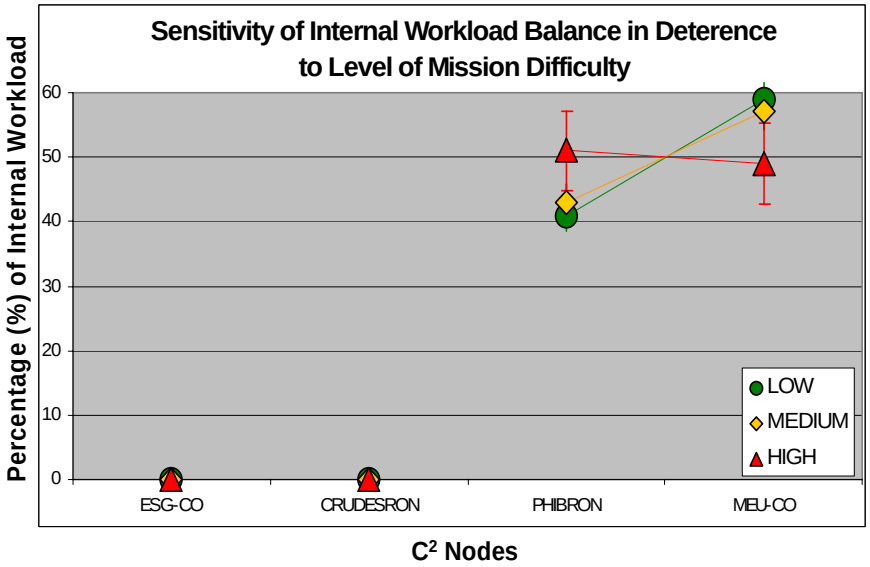


(ii)

- **Internal workload Imbalance**: at low and medium task-load, the workload is higher on the PHIBRON. However, as the task-load increases to high-level, the workload is higher on the MEU.
- **External workload imbalance:** PHIBRON has higher external workload values than the MEU-Co at all task load levels

Workload Imbalance due to Mission Difficulty

Task Load: High; Dynamic S-S Relationships



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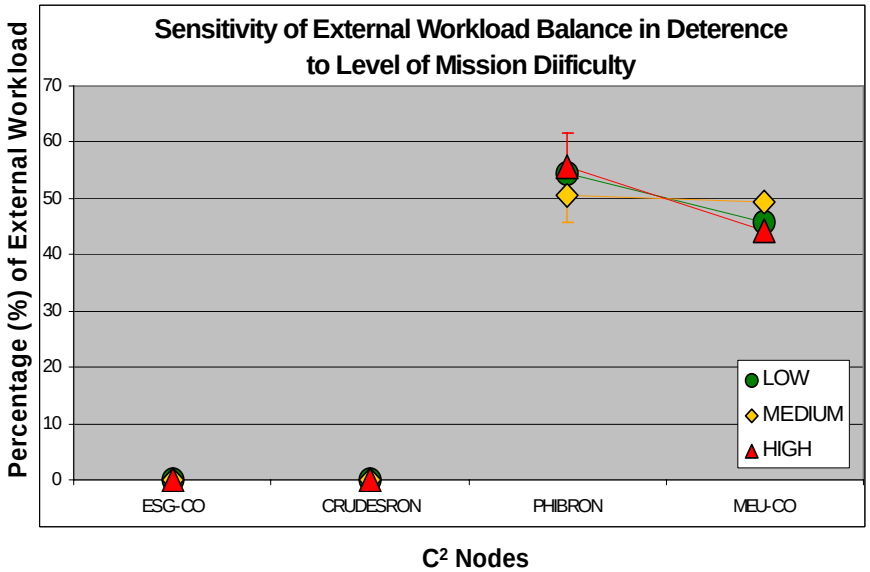

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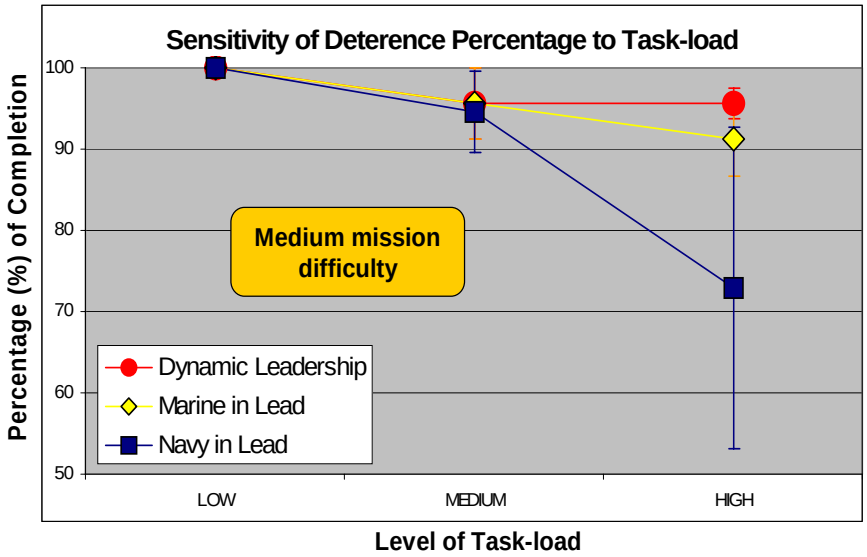
- **Internal Workload Imbalance: a**t low and medium level of mission difficulty, the internal workload is higher on the MEU-CO side. However, as the level of mission difficulty increases to high, the workload balance shifts toward an equilibrium.
- **External Workload Imbalance**: PHIBRON has a higher external workload than the MEU-CO at high-level of mission difficulty

S-S Relationships and Task Load



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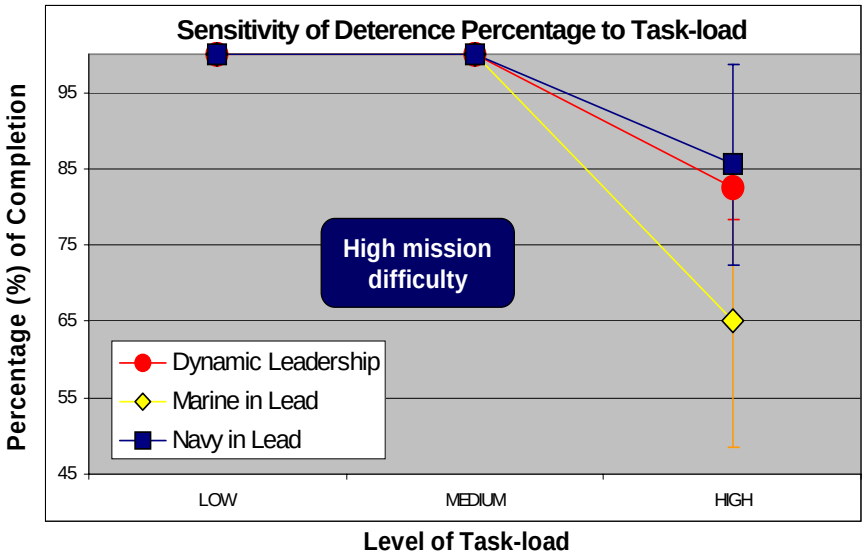
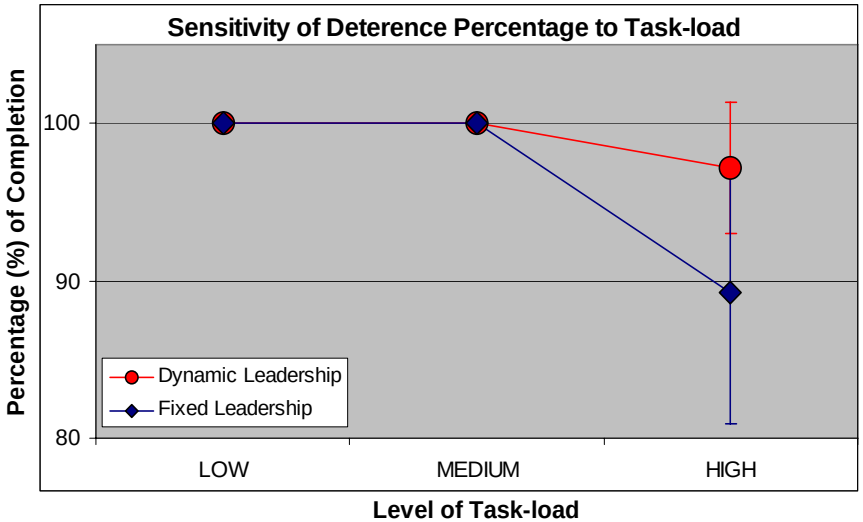


(ii)

- **Dynamic Leadership Assignment** is the Best at *all* Levels of Task load
- **Medium Mission Difficulty**: Marines in the supported role is a good alternative to Dynamic Leadership Assignment
- **High Mission Difficulty**: Navy in the supported role is a good alternative to Dynamic Leadership Assignment

Dynamic versus Mission-based S-S Relationship

Medium Mission Difficulty: Marines Supported Role
High Mission Difficulty: Navy Supported Role



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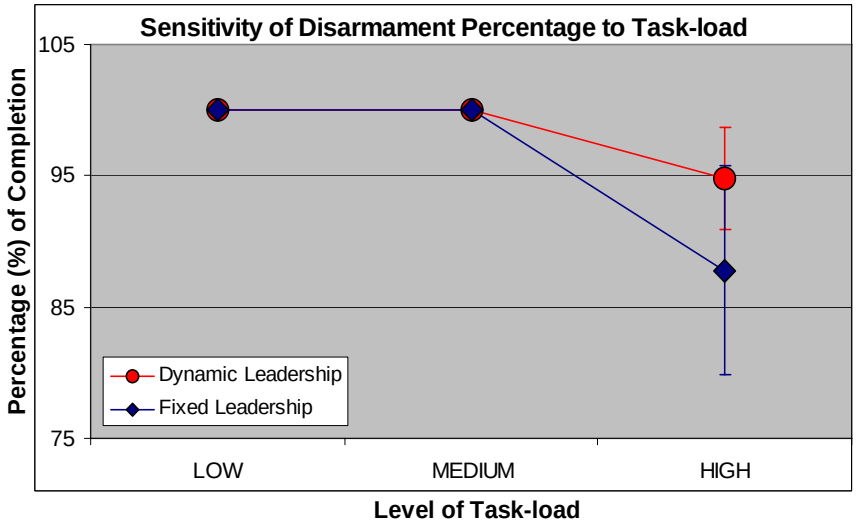

(ii)

- **Mission-based S-S Relationship performs almost as good as dynamic S-S relationship**
- **Mission-based S-S Relationship is Easier to Train**

Insights from Agent-based Simulation

- The success of the ESG will depend largely on the capability to merge the two doctrines (Amphibious and CWC) for both PHIBRON and MEU
- The training involving both Navy staffs and Marine commander with a broad set of missions is a must to diminish the gap between two entities
- The Supporting-Supported relationships should adaptive to missions and environments in order to conduct seamless co-operations
- The ESG should define clear goals for it to achieve and missions for it to conduct so that the above-mentioned exercises can be carried out successfully

Summary

- Model-based organizational analysis to systematically study ESG C^2 Structures
- **Hypothesis**: The presence of dual doctrines (Amphibious and CWC) will introduce high workload on the PHIBRON C2 node and high external coordination with other C2 nodes
  - Confirmed with respect to Task Load
  - Confirmed for Missions with High Difficulty
- Supporting-Supported Relationships
  - Dynamic S-S Relationship is the Best
  - Mission-based S-S Relationship is almost as good (easier to train)
- Enhancements to the ESG organization

1. Reinforce PHIBRON to minimize workload imbalances
2. Stream-lining the coordination processes (S-S relationships, information coordination)